U.S. Department of Transportation
Federal Highway Administration

Post-Hurricane Sandy Transportation Resilience Study in NY, NJ, and CT

MAP Forum

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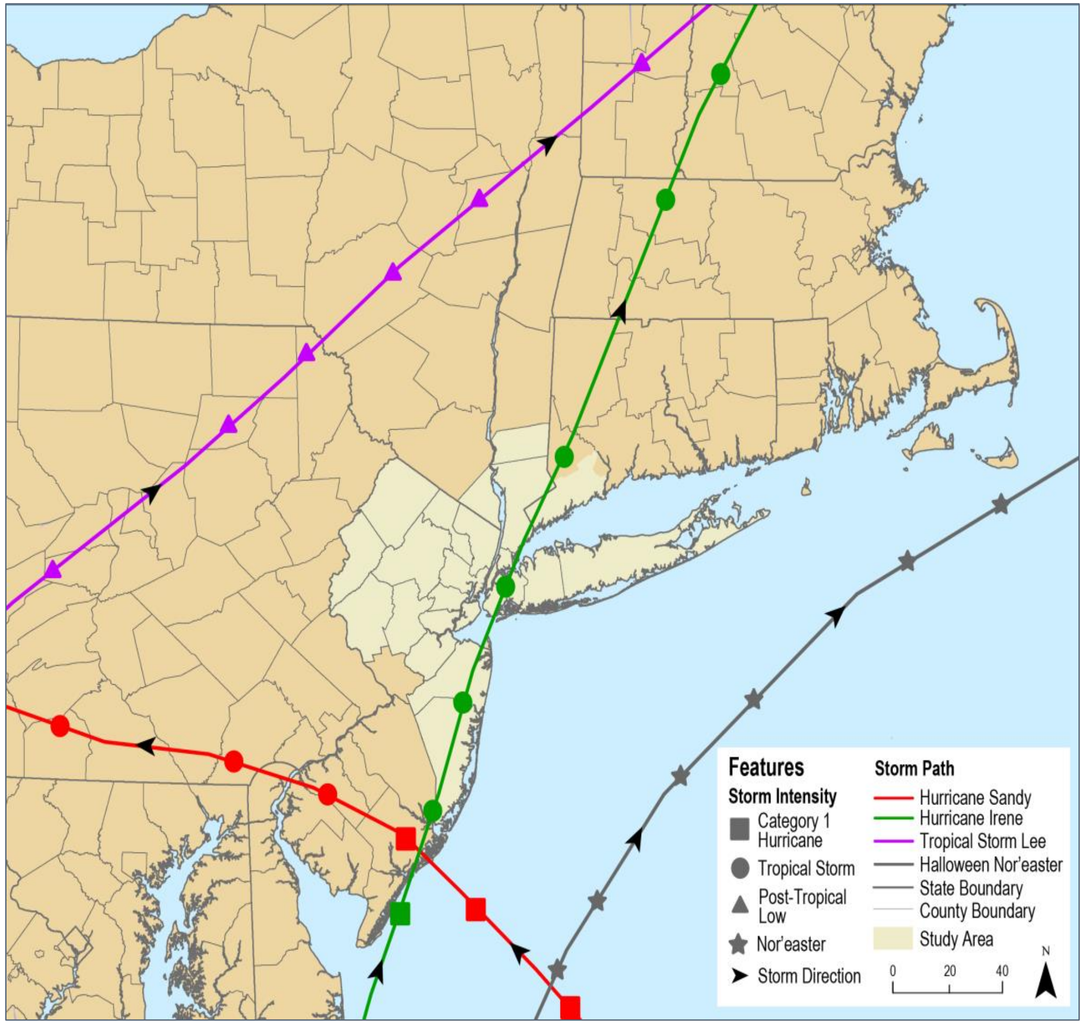
Presentation Overview

- Background
- Study Partnership
- Study Results
- Lessons Learned and Challenges
- Recommendations

Post-Sandy Study Background

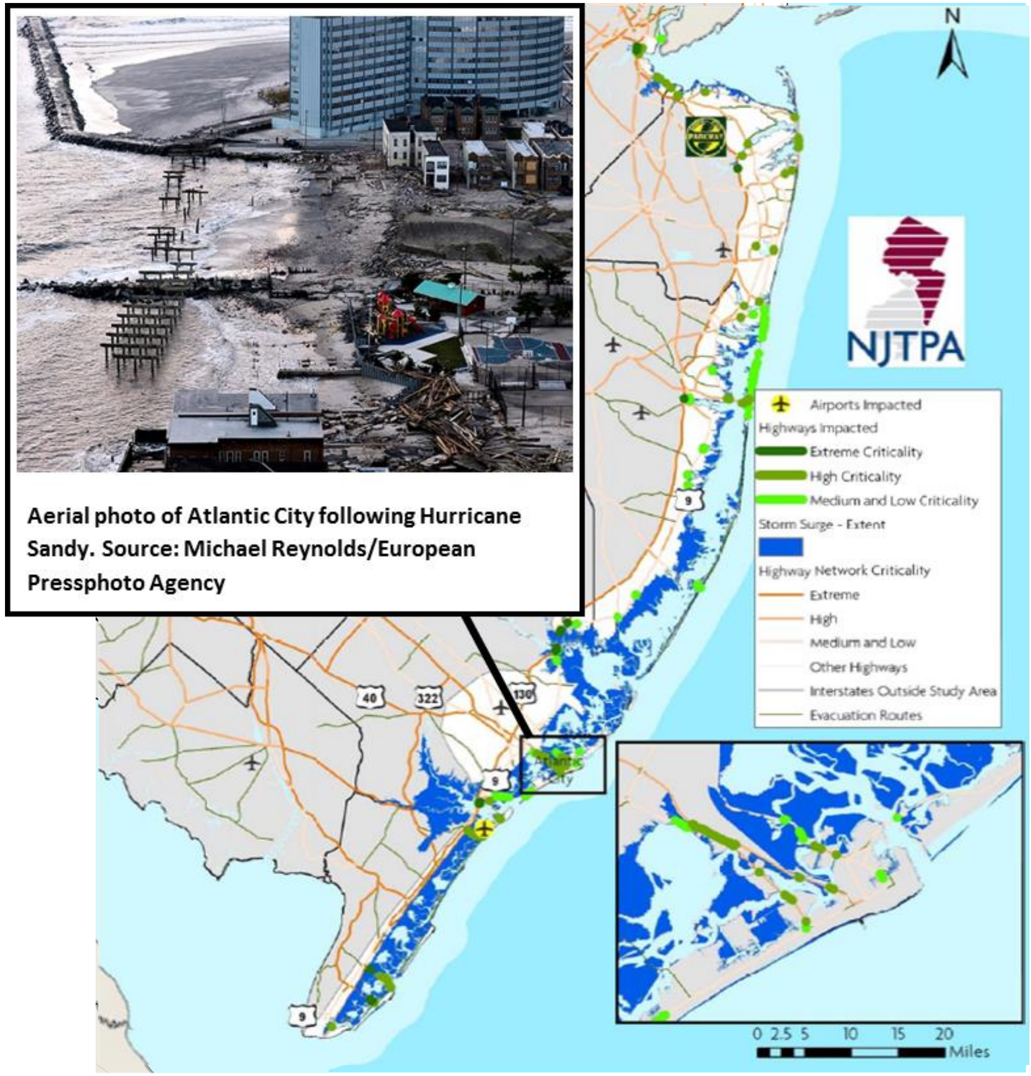
- Four extreme weather events within a fifteen-month period in 2011 and 2012:
  - Hurricane Irene
  - Tropical Strom Lee
  - Halloween N'oreaster
  - Superstorm Sandy
- Illuminated a range of transportation resilience issues in New York City's multi-state metropolitan region



Source: National Oceanic and Atmospheric Administration, Office for Coastal Management. DigitalCoast Historical Hurricane Tracks data

Post-Sandy Study Background

- Build on a FHWA 2011 NJ pilot
- Learn from experience of 2012 Hurricane Sandy other recent storms
- Identify strategies to improve resilience
- Research project launched in Fall 2013

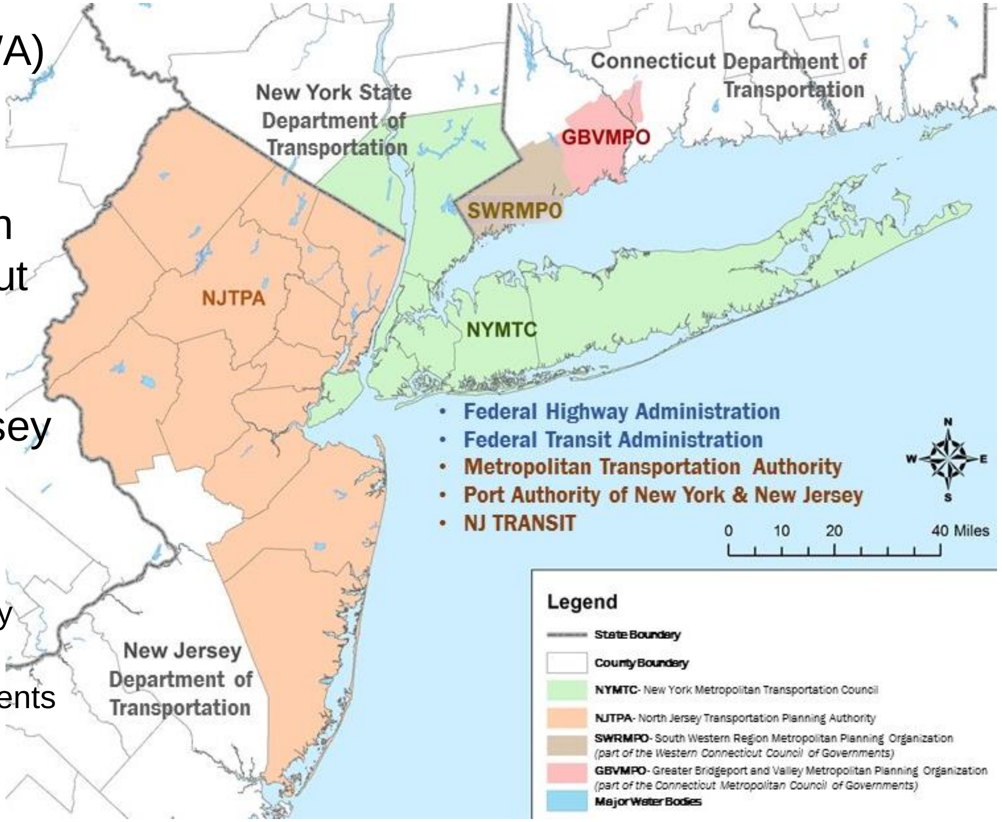


Aerial photo of Atlantic City following Hurricane Sandy. Source: Michael Reynolds/European Pressphoto Agency

SLR 1 Meter, 2100, Coastal Study Area (Roadways). Source NJTPA

Post-Sandy Study Partners

- Federal Highway Administration (FHWA)
- Federal Transit Administration (FTA)
- State Departments of Transportation in New York, New Jersey and Connecticut
- Metropolitan Transportation Authority
- Port Authority of New York & New Jersey
- Metropolitan Planning Organizations:
  - New York Metropolitan Transportation Council
  - North Jersey Transportation Planning Authority
  - Western Connecticut Council of Governments
  - Connecticut Metropolitan Council of Governments



Consulting Team:
- Cambridge Systematics
- AECOM
- Abt Associates (Stratus Consulting)
- Office of Radley Horton (Columbia U)
- C2E (Vanderbilt U)

Post-Sandy Study Objectives & Core Work Plan

- Enhance the tristate region's resiliency to climate and extreme weather in the longer term, while informing the ongoing Hurricane Sandy recovery process
- Identify feasible, cost-effective strategies to reduce and manage extreme weather vulnerabilities amid the uncertainties of a changing climate
- Advance the state of knowledge and develop methods to assist agencies in the region—and nationwide—to plan and invest for long-term climate resilience

Regional, Multi-modal Compilation of Damage and Disruption from Previous Events

System-Level Vulnerability Assessment

Three Subarea-Level Vulnerability and Risk Assessments

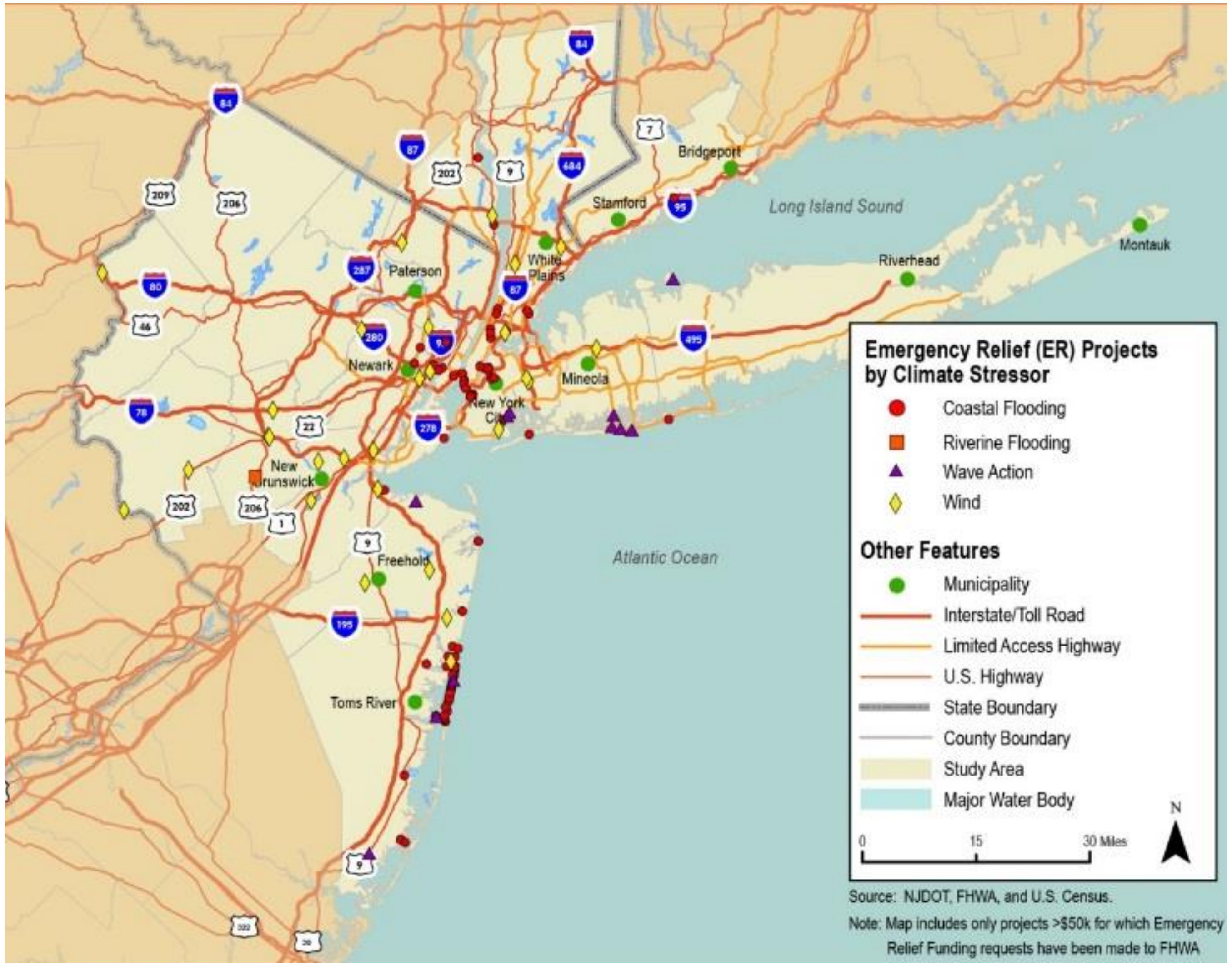
Ten Facility-Level Vulnerability and Risk Assessments with Evaluation of Potential Adaptation Strategies

Post-Sandy Study Generalized Process for Assessing Vulnerability and Risk

	Regional	Subarea	Facility
Define Climate Impacts and Scenarios for Analysis	**Consistent Assumptions**		
Assess Vulnerability • Exposure to Climate Stressors • Sensitivity of Facility/Component • Adaptive Capacity of System and Facility	Regional exposure	Corridor- or network-scale exposure, sensitivity, adaptive capacity	Facility- and component-specific exposure, sensitivity, adaptive capacity
Assess Risk • Likelihood of Damage and Disruption • Consequences	Establish policy framework (e.g., risk tolerance)	Network-scale risk assessment to identify highest priority facilities	Network-scale risk assessment to identify highest priority facilities
Formulate and Assess Potential Adaptation Strategies	General strategies relevant to region	Strategies relevant to subarea context	Facility-specific strategies; optional benefit/cost analysis

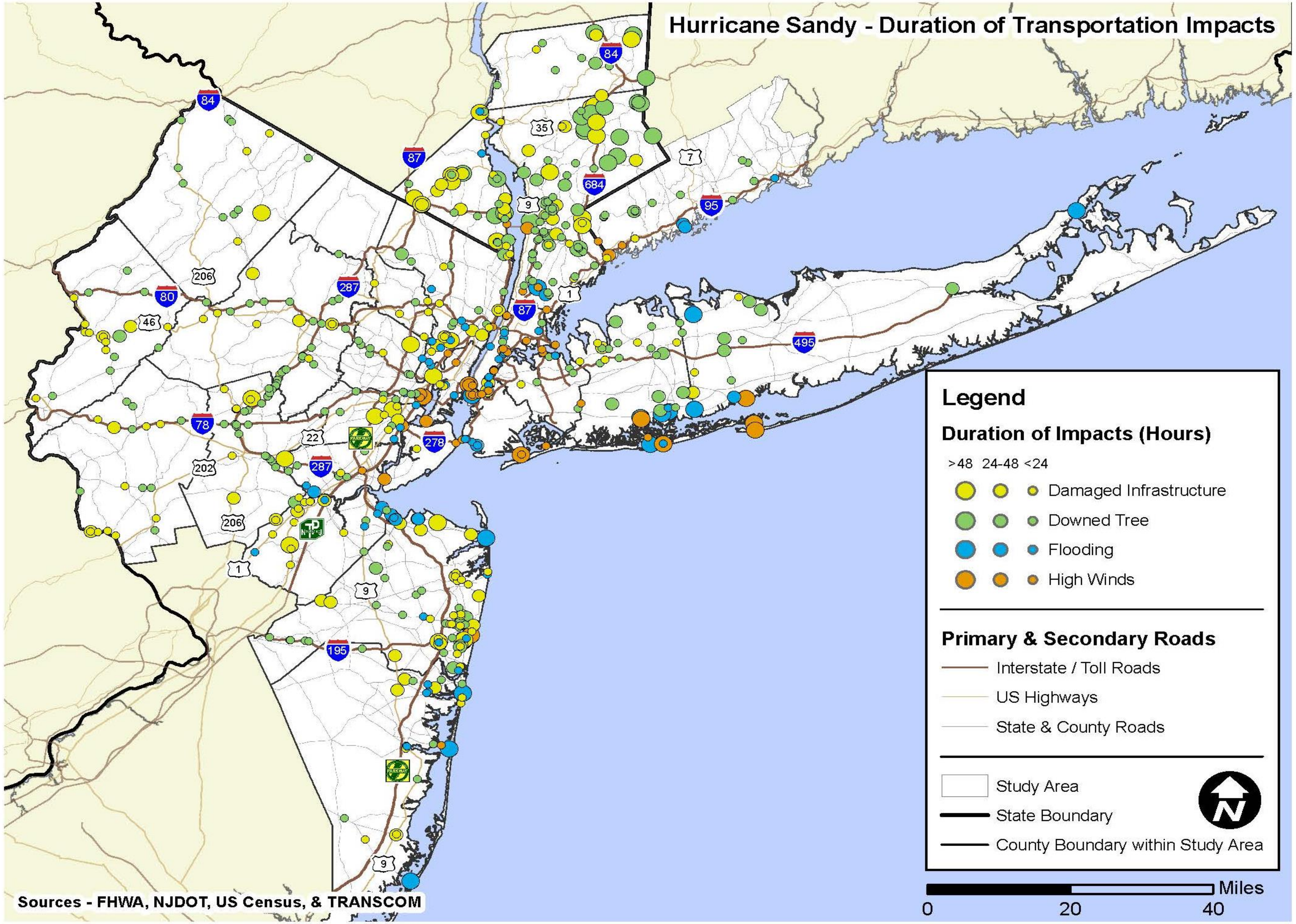
Regional Damage and Disruption Assessment

- Analyzed historical data from recent storm-related damage and disruption
  - Sandy (2012)
  - Irene (2011)
  - Lee (2011)
  - Storm Alfred (2011 nor'easter)

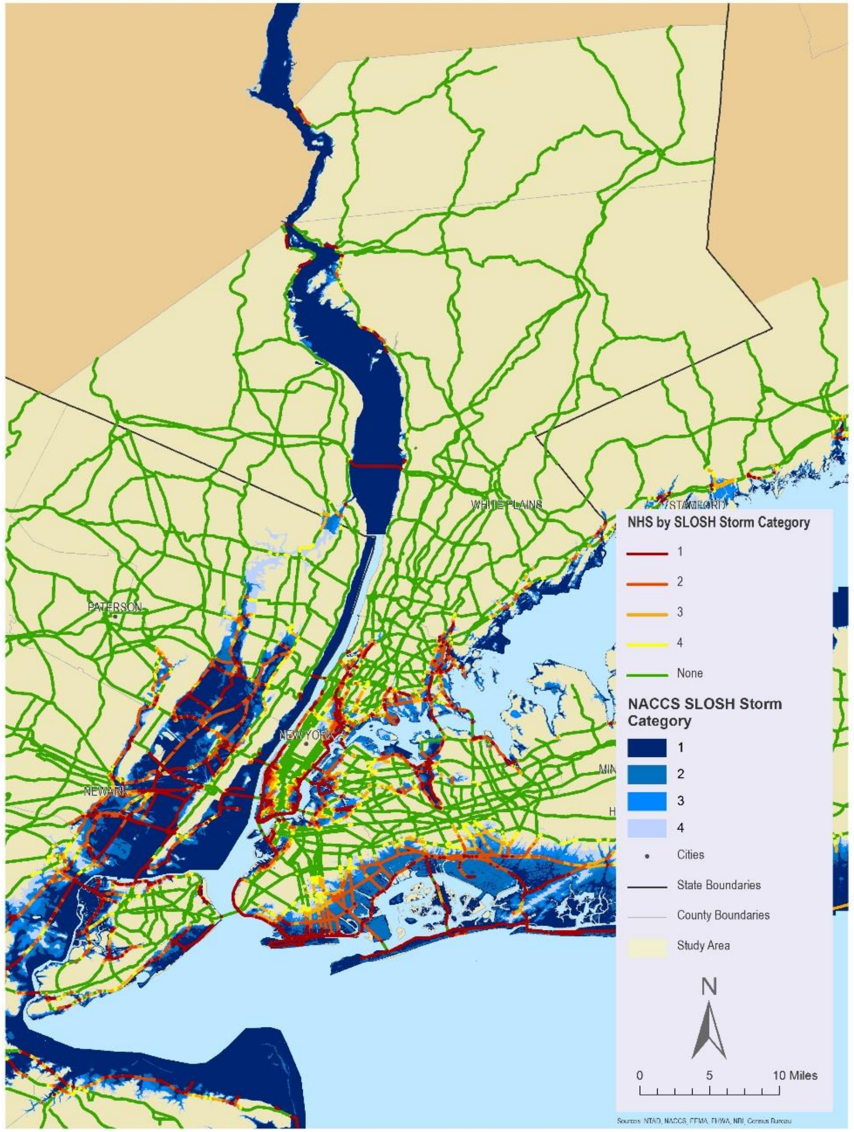


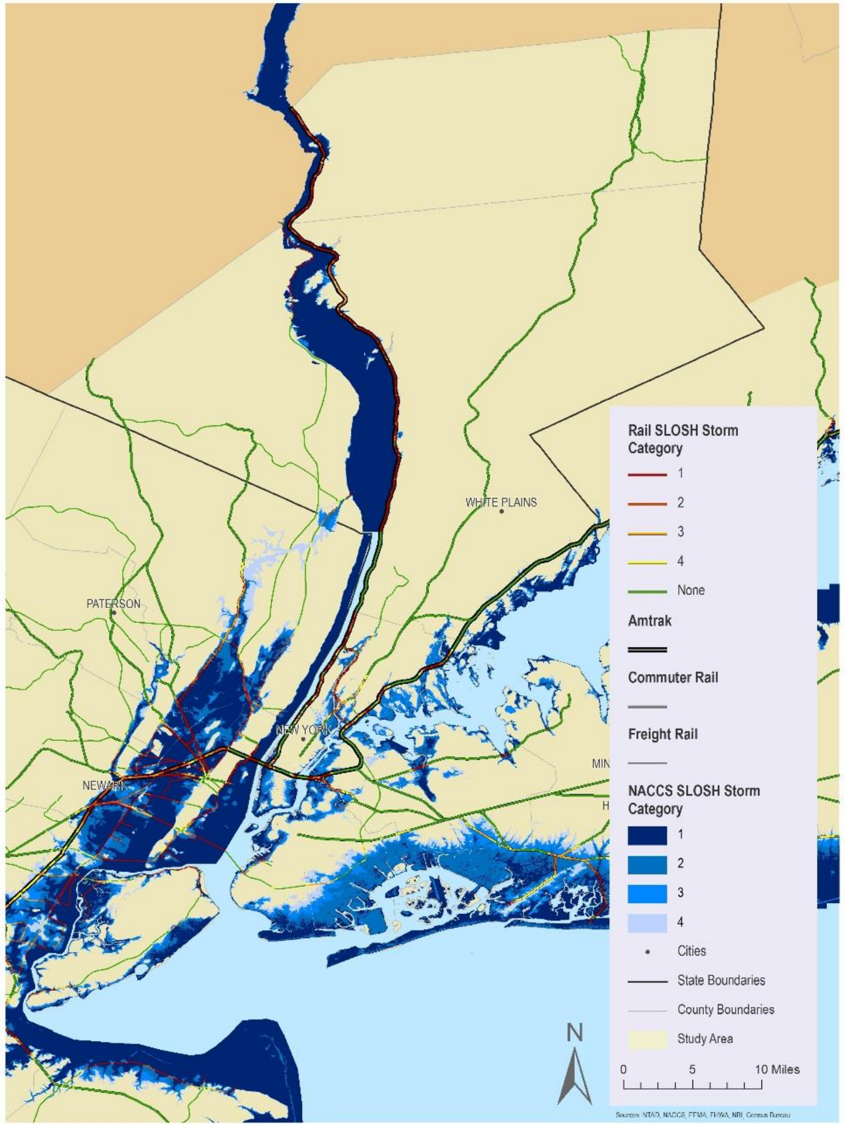
Projects Submitted to FHWA for ER Funding Reimbursement, by Climate Stressor, as of October 2013 (Hurricane Sandy)

Regional Damage and Disruption Assessment



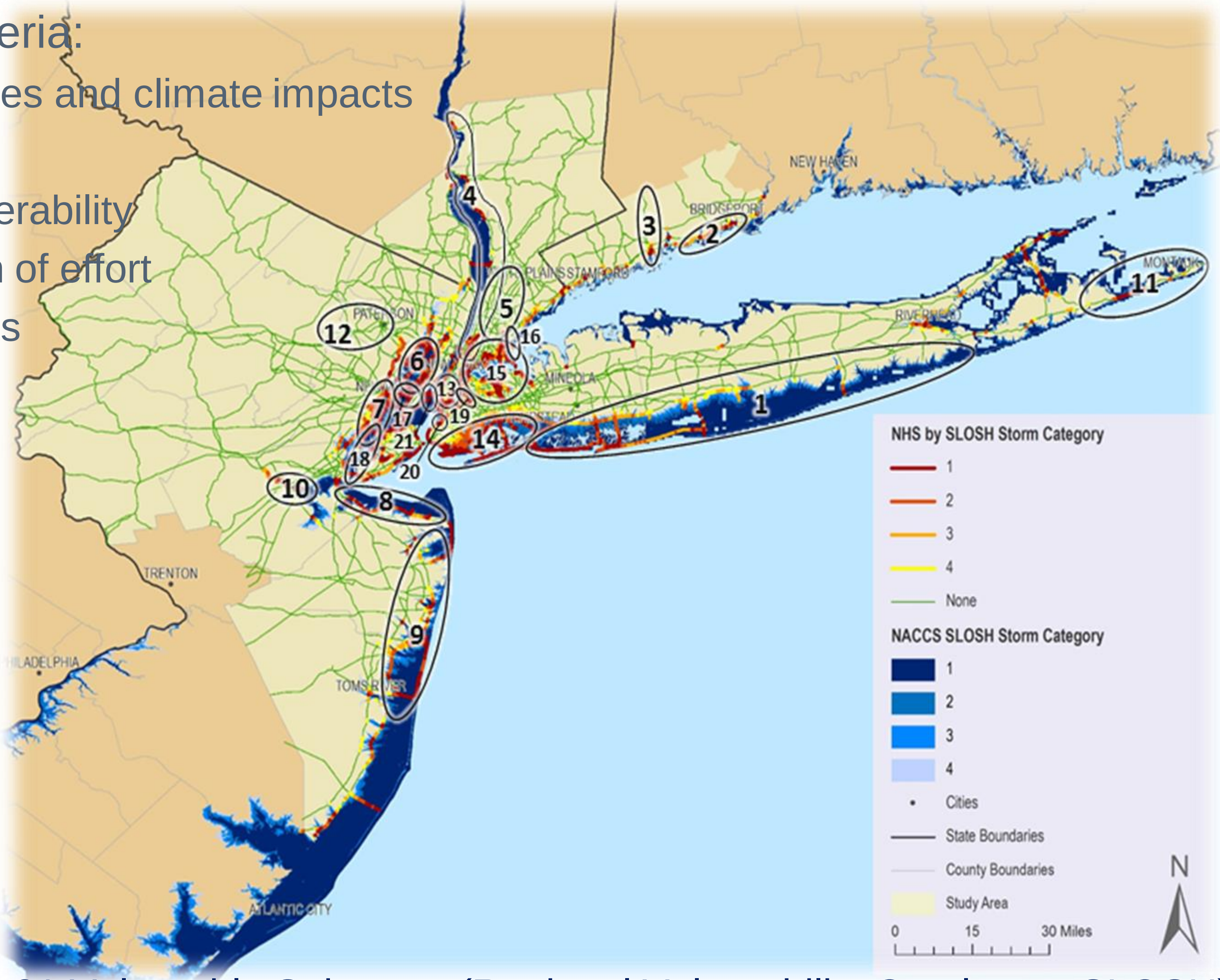
Regional Transportation System Assessment





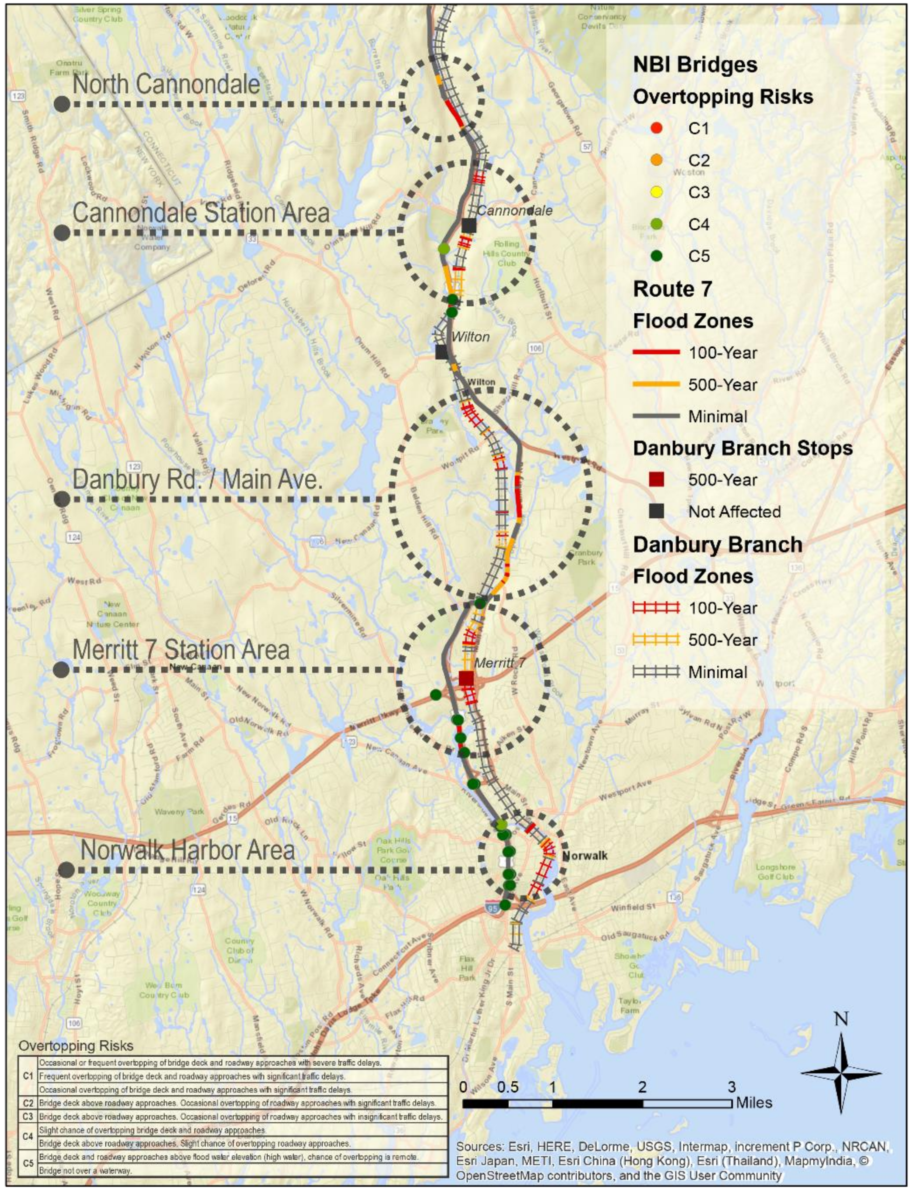
Subarea Assessments of Vulnerability and Adaptation Options

- Identified 21 vulnerable subareas
- Narrow to 3 using criteria:
  - Range of geographies and climate impacts
  - One per state
  - Relatively high vulnerability
  - Avoiding duplication of effort
  - Usefulness of results

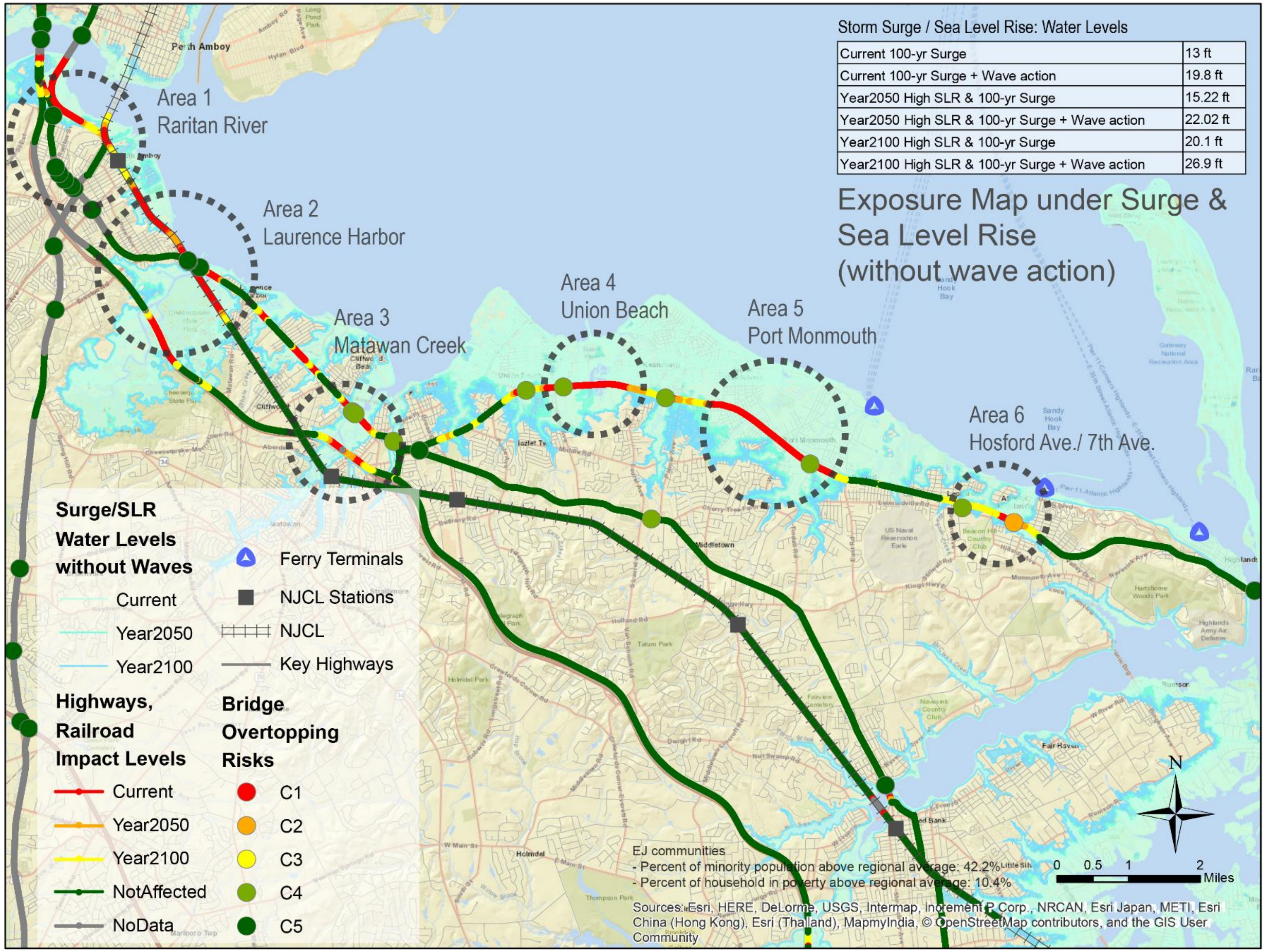


21 Vulnerable Subareas (Regional Vulnerability Overlays – SLOSH)

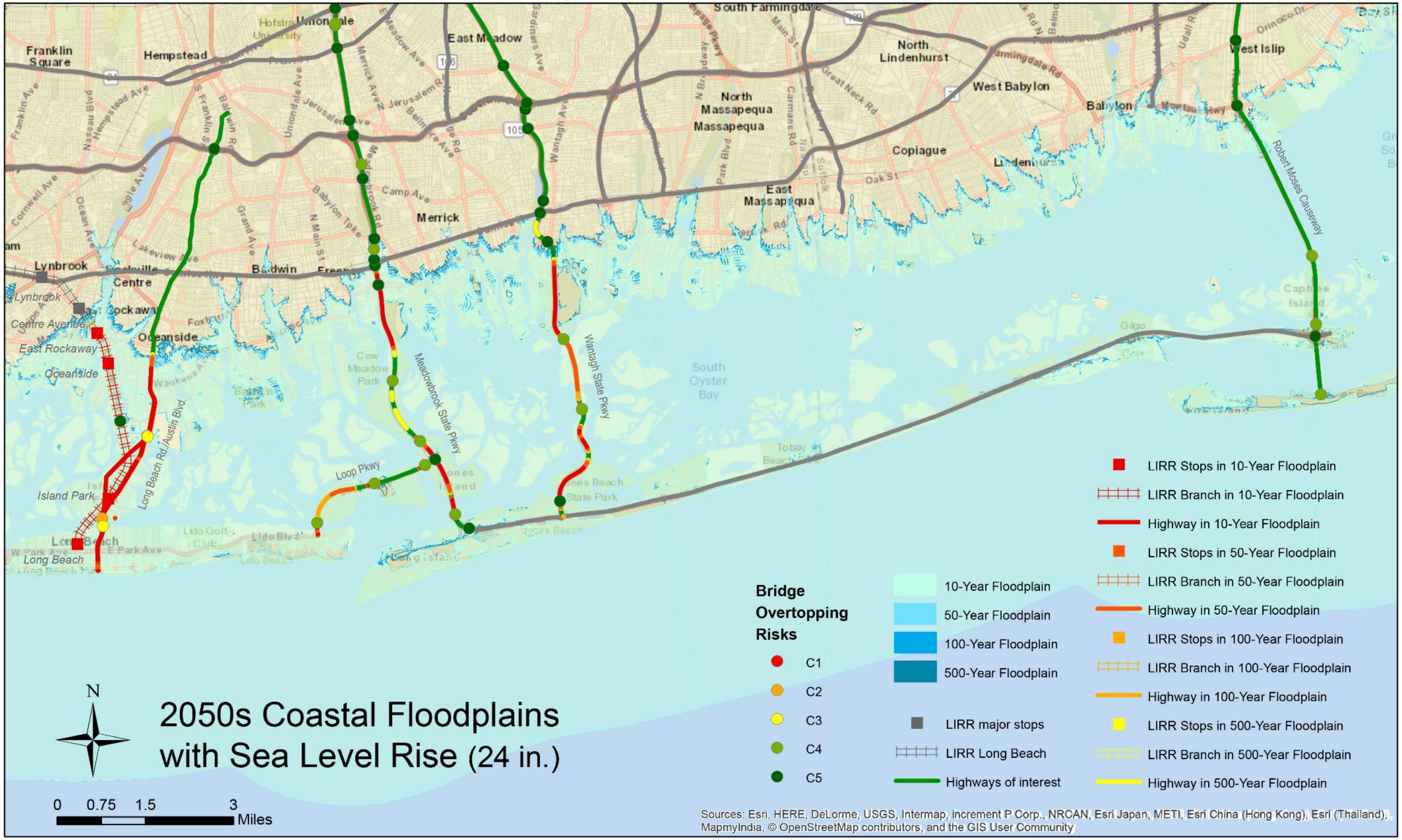
Norwalk-Danbury Corridor– Exposure Areas



Raritan Bayshore – Inundation Levels with DEMs



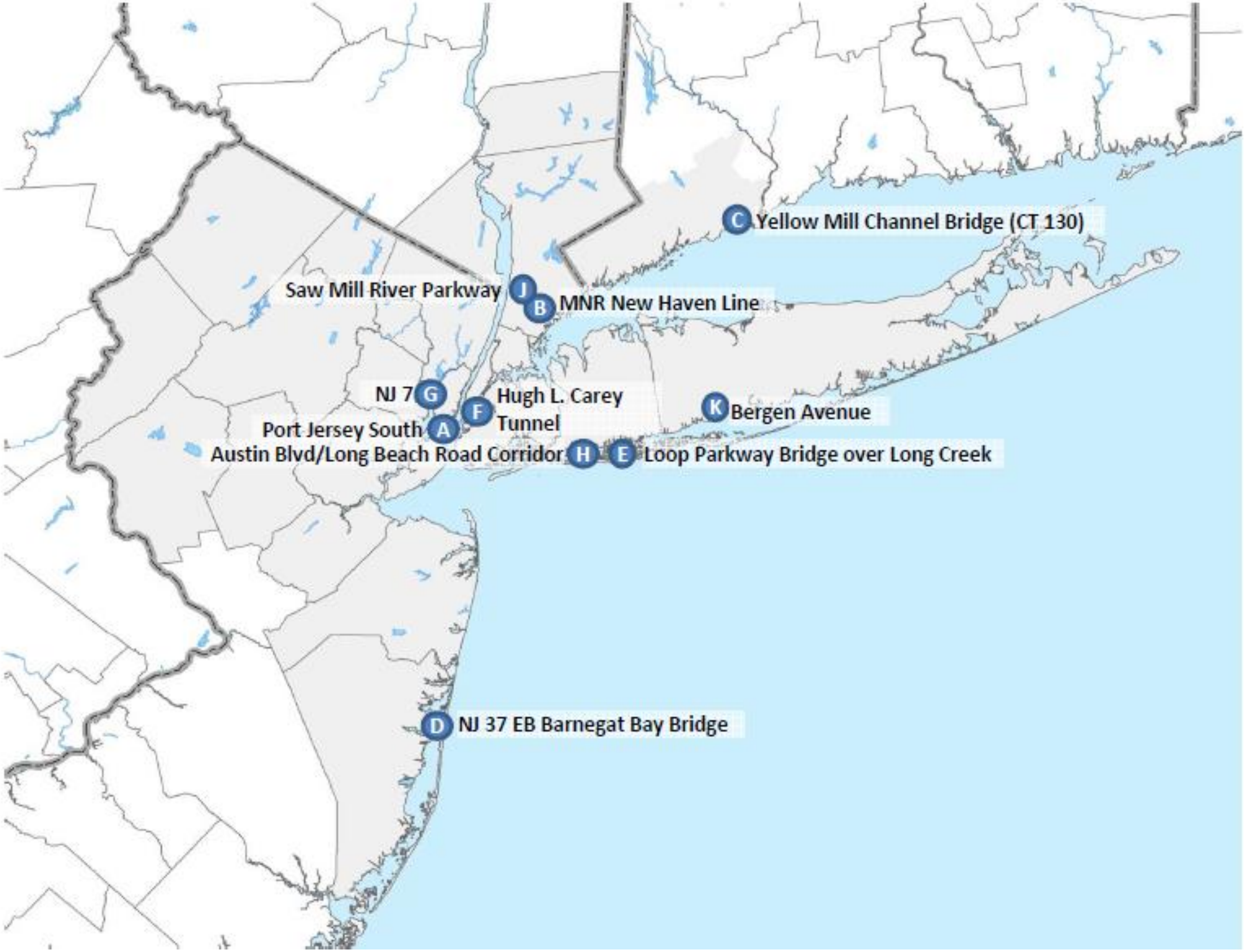
Long Island South Shore – NYSERDA Floodplains



Adaptation Matrices for Each Subarea

	Near Term	Longer Term
Higher Risk Tolerance/ Lower Investment		
Lower Risk Tolerance/ Aggressive Investment		

Facility Level Engineering Informed Assessments



Facility Level Engineering Assessment – Loop Parkway Bascule Bridge, NY

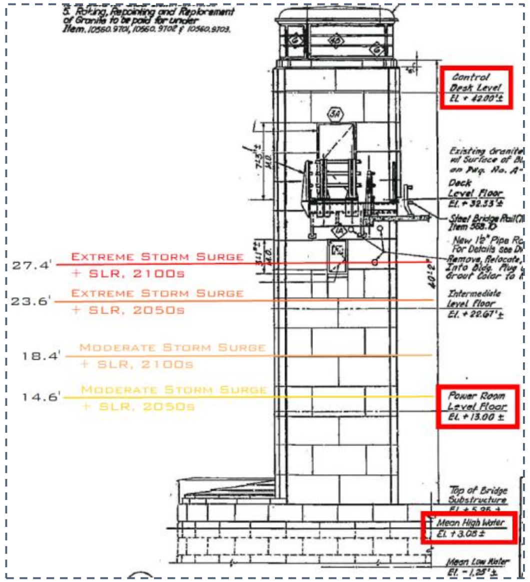
Define Climate Impacts and Scenarios for Analysis

Stressor Type	Elevation (Feet above MSL)	Analysis Year and Scenario
SLR + Moderate Storm Surge	14.6 18.4	2050s high range-estimate (90th Percentile) 2100s high range-estimate (90th Percentile)
SLR + Extreme storm surge	23.6 27.4	2050s high range-estimate (90th Percentile) 2100s high range-estimate (90th Percentile)

Assess Vulnerability
- Exposure to Climate Stressors
- Sensitivity of Facility/Component
- Adaptive Capacity of System and Facility

Impacts and Concerns:
- Electrical and mechanical equipment for opening the bridge suffered major damage due to water in the equipment housing
- Drawbridge operations were suspended for 3 days while electrical repairs were performed

Components of the Bridge examined include:
- mechanical items (motors, back-up generator and machinery that drive the bascule span lift operation);
- electrical items (wiring and electrical switches and controls);
- structural items (comprised of piers and the superstructure - assessed nominally as part of the entire Bridge structure).



Assess Risk
- Likelihood of Damage and Disruption
- Consequences

- Use/ridership: Carries two lanes in each direction with AADT of 30,302
- Criticality: Serves as hurricane evacuation route and is the only state highway access to City of Long Beach, Lido Beach, Atlantic Beach Point Lookout and other communities of the barrier island. Long Creek is most utilized navigable channel in the area

Formulate and Assess Potential Adaptation Strategies

Option 1 for Power Room:
- Relocate the flood-vulnerable equipment in the existing power room above the storm surge + SLR level for 2100.
- New room could either be supported by the existing pier, or on a separate adjacent structure.
- Consultation required with the State Historic Preservation Office due to the historic significance of the Bridge

Option 2 for Power Room:
- Maintain the power room in place, and install flood walls and waterproofing measures to protect equipment from anticipated sea level rise, storm surge for 2100

Lessons Learned and Challenges

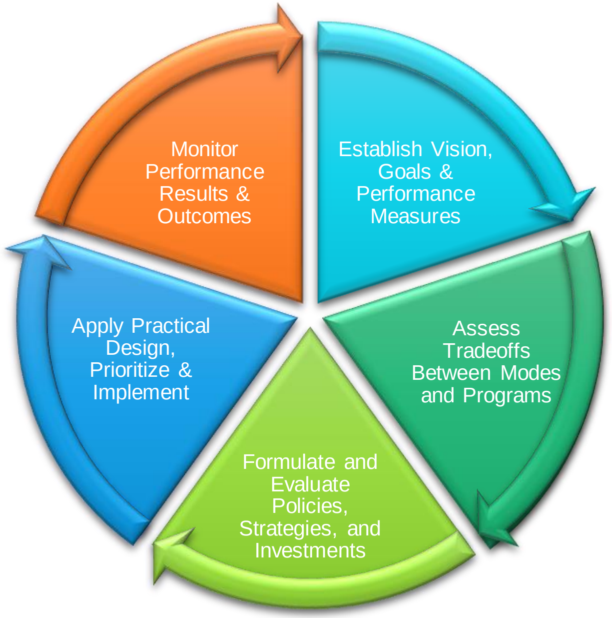
- Details and nuances of climate science and climate data are new concepts to most stakeholders
- Engage and facilitate communication between climate scientists, planners, and engineers from the start and throughout the process to ensure outcome is useful
- Understand data availability and relevance to decision making; set scope and expectations accordingly
- Most significant drivers of vulnerability, risk, and cost of adaptation strategies can be most difficult to assess (e.g., long term effects of saltwater exposure or economic impacts of transportation system disruption)

Barriers to Effective Adaptation

- The variety of climate projections available to the process, particularly with regard to sea level rise;
- Incomplete historical information on the impacts of weather events on the regional transportation system;
- Availability of transportation asset-related information and data;
- The multiplicity of governmental and agency responsibilities and jurisdictions;
- Legal and regulatory hurdles; and
- Limited resource availability for adaptation measures.

Post-Sandy Study Recommendations: Implementing Resilience in Transportation Decision-making

Generic Transportation Planning and Programming Cycle



Step	Opportunities to Integrate Climate Vulnerability and Risk
Establish Vision, Goals & Performance Measures	• Consider resilience to climate change in each element of policy framework for statewide and regional long range plans, transportation improvement programs, risk-based transportation asset management plans, and mode-specific plans. • Establish regional and statewide performance measures related to climate change, resilience, and sustainability.
Assess Tradeoffs Between Modes and Programs	• Include climate risk as one key element of an agency's broader risk management framework. Include climate-related risks in agency risk register. • Test implications of various funding allocation decisions at the level of program areas and modes. How do investments in adaptation strategies vs. safety vs. pavement/bridge maintenance vs. mobility affect a state's or region' s ability to meet short-term and long-term performance targets?
Formulate and Evaluate Policies, Strategies, and Investments	• Propose specific adaptation strategies based on assessment of regional, subarea, and asset-level vulnerability and risk. • Consider cost and feasibility of options. Some adaptations may be relatively expensive (perhaps requiring additional sources of revenue or outside financial support).
Apply Practical Design, Prioritize & Implement	• Make changes to assumptions about climate stressors, particularly for asset classes that have longer useful life and are in high-risk areas. • Conduct "bottom up" prioritization of adaptation investments to complement "top down" program-level tradeoff analysis. • Program adaptation strategies at appropriate time frames given understanding of pace of climate change (including timing of risks) and key milestones.
Monitor Performance Results & Outcomes	• Monitor changing climate conditions and keep abreast of latest climate projections and models to inform design and prioritization decisions. • Amass database of weather events that cause damage or disruption to the transportation system. Archive operational data and damage reports, including costs and duration of closure. • Conduct "plan vs. actual" analysis to measure effectiveness of adaptation investments in reducing or mitigating damage and disruption.

Available Materials

https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/hurricane_sandy/index.cfm

- Final Report
  - Section 1: Overview
  - Section 2: Storm Conditions, Damage and Disruption
  - Section 3: Climate Data and Analysis Tools
  - Section 4: Assessing Vulnerability, Risk, and Adaptation Options in the Three State Metropolitan Region
  - Section 5: Integrating Climate Resilience in Transportation Decision-making
- Appendix A: Historical Damage and Disruption
- Appendix B: Facility Level Vulnerability and Risk Assessment Process
- Appendix C: Regional Exposure Analysis
- Appendix D: Subarea Assessments of Multimodal Corridors and Networks
  - 1 – New York: Long Island South
  - 2 – New Jersey: South Shore of Raritan Bay
  - 3 – Connecticut: Norwalk-Danbury Corridor
- Appendix E: Facility Level Engineering Informed Adaptation Assessments
  - Port Jersey South
  - MNR New Haven Line
  - Yellow Mill Channel Bridge
  - Barnegat Bay Draw Bridge
  - Loop Parkway Bridge
  - Hugh L. Carey Tunnel/ Governor’s Island Ventilation Building
  - NJ Route 7
  - Long Beach Road
  - Saw Mill River Parkway
  - Bergen Avenue
- Appendix F: Resources